

Final Technical Report

NASA Project: Age Dating Merger Events in Early Type Galaxies via the Detection of AGB Light.

NASA products used: 2MASS Extragalactic Catalog

Principal Investigator: G. Bothun, Department of Physics, University of Oregon

Abstract

A thorough statistical analysis of the J-H vs. H-K color plane of all detected early type galaxies in the 2MASS catalog with velocities less than 5000 km/s has been performed. This all sky survey is not sensitive to one particular galactic environment and therefore a representative range of early type galaxy environments have been sampled. Virtually all N-body simulation so major mergers produces a central starburst due to rapid collection of gas. This central starburst is of sufficient amplitude to change the stellar population in the central regions of the galaxy. Intermediate age populations are given away by the presence of AGB stars which will drive the central colors redder in H-K relative to the J-H baseline. This color anomaly has a lifetime of 2-5 billion years depending on the amplitude of the initial starburst. Employing this technique on the entire 2MASS sample (several hundred galaxies) reveals that the AGB signature occurs less than 1% of the time. This is a straightforward indication that virtually all nearby early type galaxies have not had a major merger occur within the last few billion years.

1. Analysis

We performed a two-fold analysis when examining E and S0 galaxies for centralized AGB light in the 2MASS extended source catalog. Using the 2MASS database, we searched for galaxies where the H-K color was greater than 0.3 for 2 different aperture sizes then performed photometry on the corresponding image files provided by 2MASS.

1.1. Catalog Search

Our sample size consisted initially of 427 galaxies of which there were 250 elliptical, 171 lenticular and 6 of either S0/E or E/S0 type. The morphological types were determined from the NASA/IPAC Extragalactic Database and the Third Reference Catalogue of Bright Galaxies (RC3) (de Vaucouleurs, G. et al., 1991). Of the 427 galaxies, 412 were listed in the 2MASS Extended Source Catalog (Jarrett et al., 2003). We limited our search to galaxies with redshifts under 5000 km/s as to avoid offsets in the JHK bands. The 2MASS catalog contains several magnitudes based on a wide range of aperture sizes for the J ($1.25\mu m$), H ($1.65\mu m$) and K ($2.17\mu m$) bands. For our study, we selected magnitudes measured from an ellipse fitted isophote aperture and a 5 arc sec radius circular aperture. The isophotal aperture is determined by fitting an ellipse to an isophote with a mean surface brightness of 20mag/arcsec^2 in the K_s band. The isophote is about 1σ above the background noise. Thus it follows that the aperture size varies from galaxy to galaxy. More information on the isophotal aperture can be found on the IPAC/2MASS website. Figure 1 shows a color-color plot of all 412 galaxies using the isophotal aperture. The greatest concentration of galaxies is distributed almost symmetrically between $J - H \sim 0.6$ to 0.8 and $H - K \sim 0.2$ to 0.3 . All outliers from this central distribution with H-K greater than 0.3 are potential recent mergers having a centralized AGB population. Of the 412 galaxy sample, 24 have a color $H - K > 0.3$ calculated from the 20mag/arcsec^2 isophotal aperture. A list of these galaxies is given in table 1.

Figure 2 shows a color-color plot using the 5 arcsec aperture. The distribution of galaxies has a slight linear trend (increasing J-H value for increasing H-K) with most of the galaxies falling between $J - H \sim 0.6$ to 0.75 and $H - K \sim 0.2$ to 0.3 . Again, all possible candidates lie above $H - K = 0.3$. It must be noted here that of the 412 galaxies there were 64 which did not have 5 arcsec aperture information listed in the catalog. For these, we calculated the magnitudes at 5 arcsec apertures using the QPHOT routine in IRAF on 2MASS images. Details of this process are explained in section ? of this paper. Galaxies NGC 147, NGC 3136 and NGC 4696 were not analyzed due to low brightness (NGC 147) or light contamination due to foreground stars (NGC 3136, NGC 4696). Table ? lists the 25 galaxies which have

$H - K \geq 0.3$ for the 5 arcsec aperture. We excluded galaxies which are already included in table ?. In all, there are 49 candidate galaxies with possible centralized AGB populations.

1.2. Photometry

All galaxy images were downloaded from the 2MASS Extended Source Image Server either as 6 dimensional fits cubes or, if galaxies exceed 2 arcmin in size, individual mosaic fits files from the Large Galaxy Atlas. Each fits cube was separated into J , H and K_s bands which correspond to planes 1 – 3 of each file. All downloaded fits files were already dark-subtracted and flat-fielded and sky-illumination corrected (2MASS All-Sky Data Release Explanatory Supplement section IV.2) and have a resolution of 1 arcsec per pixel. Galaxy images that were either under 30 arcsec or near the edge of the image frame were not analyzed. Circular aperture photometry was performed on the remaining 41 galaxies using *QPHOT* in the IRAF apphot package for radii ranging from 1 to 20 arcsec in 1 arcsec increments. All magnitudes calculated were referenced to the photometric zero point values given in the fits header for each band.

1.3. Calibration

Magnitudes calculated from *QPHOT* were calibrated to magnitudes from table 1 in Silva & Bothun (1998a, hereafter referred to as SB1998a), which we show here in table ?. The aperture diameters D_n , originally determined by Dressler et al (1987), are in units of $\log(\text{arcseconds}/6)$. An offset or "zero point" for color bands $H - K$ and $J - H$ was calculated between the 2MASS and SB1998a magnitudes by performing photometry on the SB1998a galaxies using the equivalent 2MASS image files at the listed D_n aperture. Subtracting the SB1998a sample magnitudes from the 2MASS *QPHOT* values for the same galaxies, we obtained the zero points of 0.029 ± 0.033 and 0.022 ± 0.023 for $H - K$ and $J - H$, respectively. In turn, these offsets were applied to the photometric results for the 41 galaxies obtained from the 2MASS image server. Figure 3 shows a color plots of the final calibrated galaxies as a function of aperture radius.

2. Results

Galaxies NGC 3390, 4710 and 5866 are significantly redder near their centers. However their $J-H$ colors are greater than 0.8 for the same radii which is not consistent with the AGB

population color.

In general, the statistical results from this catalog search and subsequent measurements confirm the more targeted survey of Silva and Bothun (1998). The occurrence or prevalence of AGB light in nearby early type galaxies is remarkably rare. This is not a detector sensitivity issue more than sufficient S/N occurs to easily detect the color differences that reveal the presence of this population. Our detection rate is much less than 1% of the total sample size. This is a direct indication that most nearby early type galaxies **can not be** the result of mergers that happened within the last 3-5 billion years, else this stellar population signal would have been observed. This provides a strong indication that if the majority of early type galaxies did indeed form via the merger process, that event occurred early in the history of the evolution of these galaxies and is not a late event as others have speculated. This basic result is robust simply because our analyzed sample size is 20 times bigger than previous studies and it is an all sky survey meaning that it includes all types of environments, including dense clusters where one might expect recent mergers to have occurred. Apparently they have not.

This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation. This research has made use of the NASA/IPAC Extragalactic Database (NED) which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.



